Midlatitude cyclones: cloud distribution in warm fronts

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The classical picture

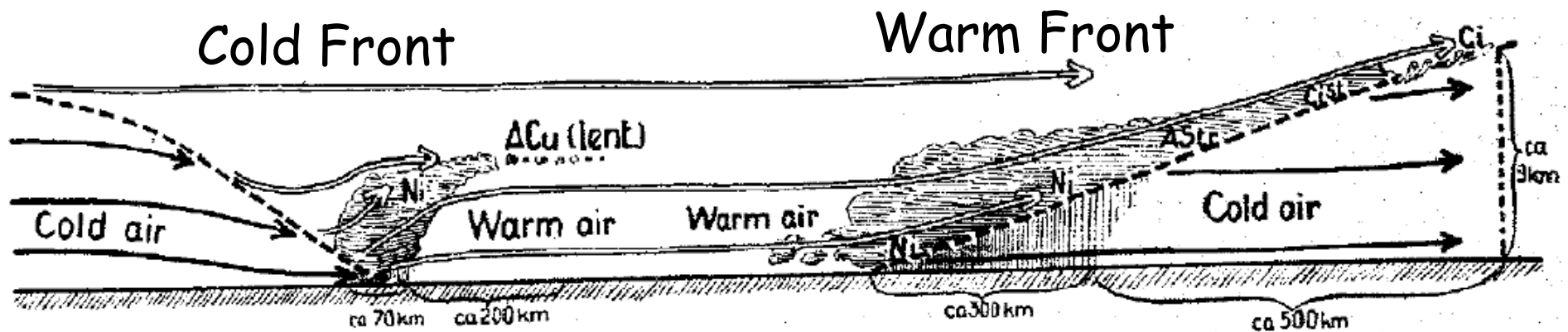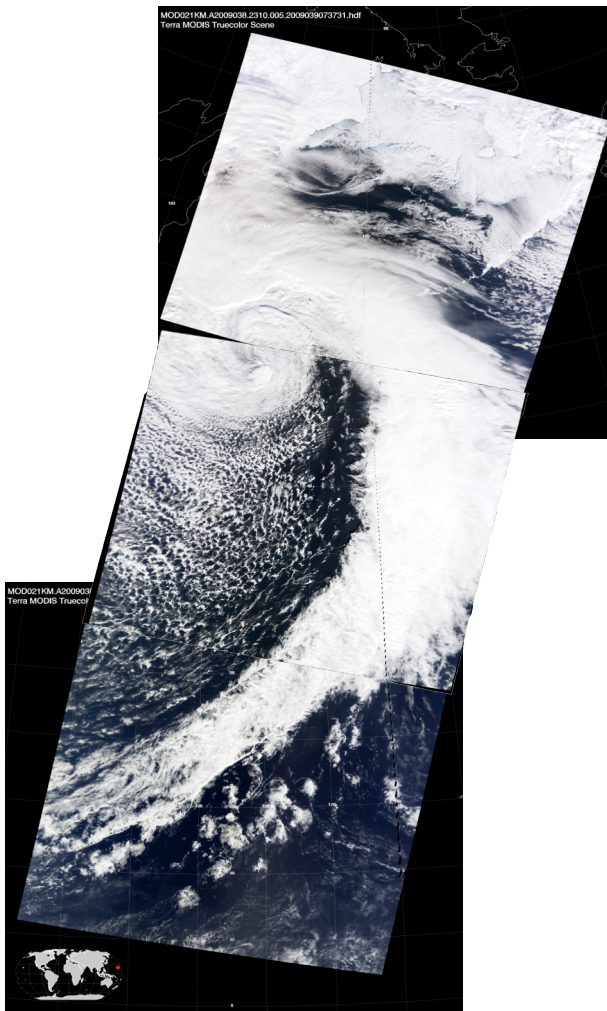- Bergen school, 1920's, based on accounts from ground based observers

Fig. 1.
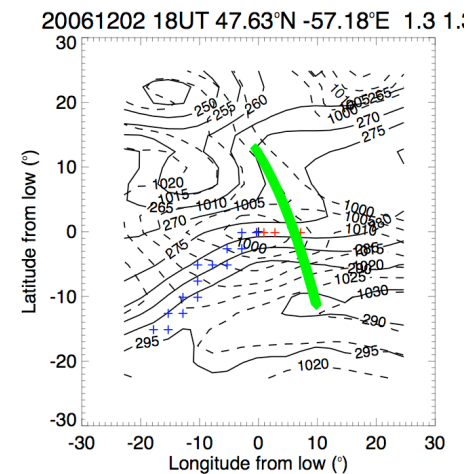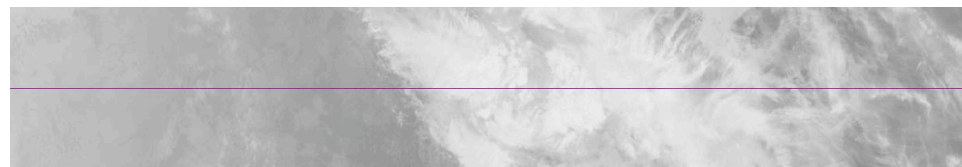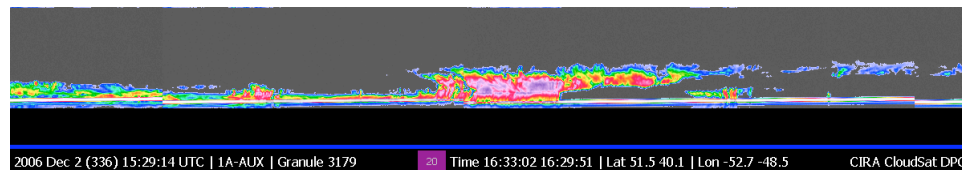Idealized cyclone.

Top view: satellites

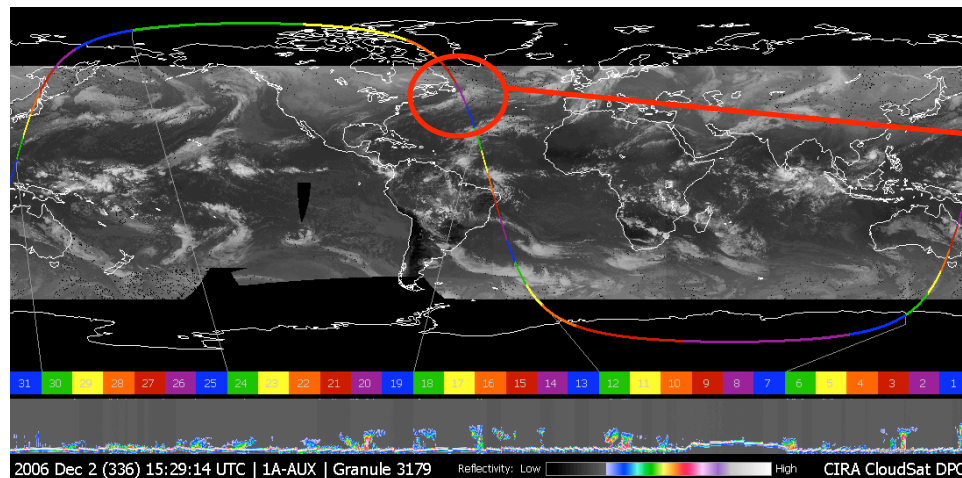- Since the 1970s, satellite offer new perspective

- Example from MODIS TERRA, 2/07/2009, 2310-2320 UT

View inside?

- Aircrafts: not exactly safe nor pleasant
- Active instruments, such as Radars: much better, ground based ok but on polar orbiter even better
- 35GHz or 94-95 GHz, "cloud" radars sensitive to hydrometeors (precip+clouds)
- CloudSat: 2D slices of troposphere, available since June 2006

CloudSat: Dec 2 2006

2006 Dec 2 (336) 15:29:14 UTC | 1A-AUX | Granule 3179   Reflectivity: Low ▮▮▮▮ High   CIRA CloudSat DPC

2006 Dec 2 (336) 15:29:14 UTC | 1A-AUX | Granule 3179   20 Time 16:33:02 16:29:51 | Lat 51.5 40.1 | Lon -52.7 -48.5   CIRA CloudSat DPC

Source: http://www.cloudsat.cira.colostate.edu

20061202 18UT 47.63°N -57.18°E 1.3 1.3

SLP contours (dashed), temperature contours (solid), centered on low found at 47.63N- 57.18W (Atlantic ocean). Red +: warm front; blue +: cold front; green line: CloudSat orbit

20061202 18UT 47.63°N -57.18°E 1.3 1.3, warm fror
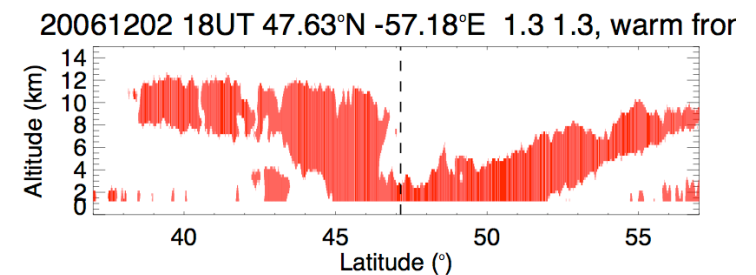
CloudSat cloud mask along orbit center on intersect with warm front (flag between 20 and 40 included)

Vertical cloud frequency of occurrence across warm fronts

- 2 questions:
  - on average, are CloudSat observations giving us a cloud distribution close to classical picture?
  - Can the GISS GCM give cloud distributions similar to the observations?

- 2 winters of NCEP and CloudSat observations (2006-2007 and 2007-2008) for north Atlantic and north Pacific (30-50 °N)

- NCEP midlatitude cyclone database, MCMS, by M. Bauer + surface winds and temperature gradient => warm fronts

- Build composite of cloud frequency of occurrence based on CloudSat cloud mask in cross-section perpendicular to warm front

- => 39 warm front crossings in NCEP/CloudSat

CloudSat cloud frequency of occurrence across warm fronts

Compared to Bergen representation: low level clouds present prior and after the front, and more high-level clouds in warm sector

All, OCEAN_goodwarm
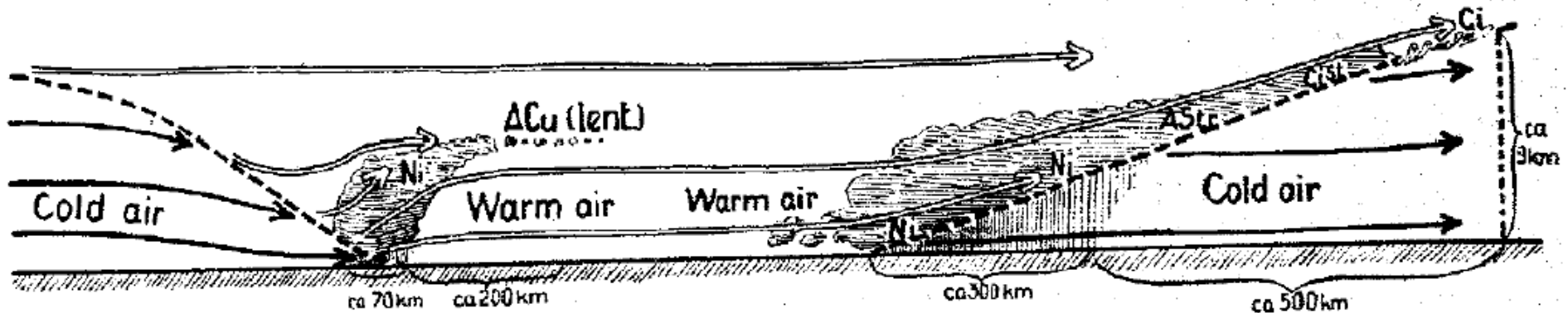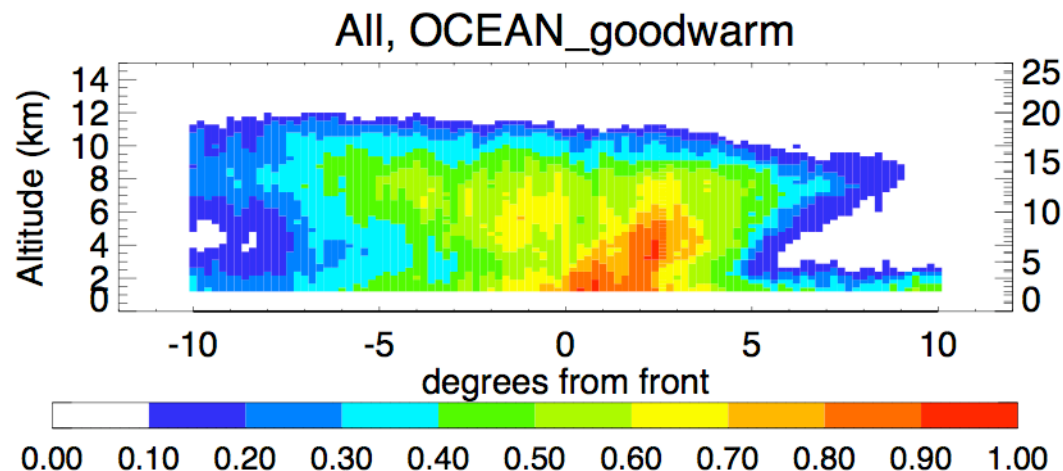
Simulated frequency of occurrence of clouds in warm front

GISS GCM cloud fraction across warm front: ocean_850m

Cloud fraction from GISS-GCM
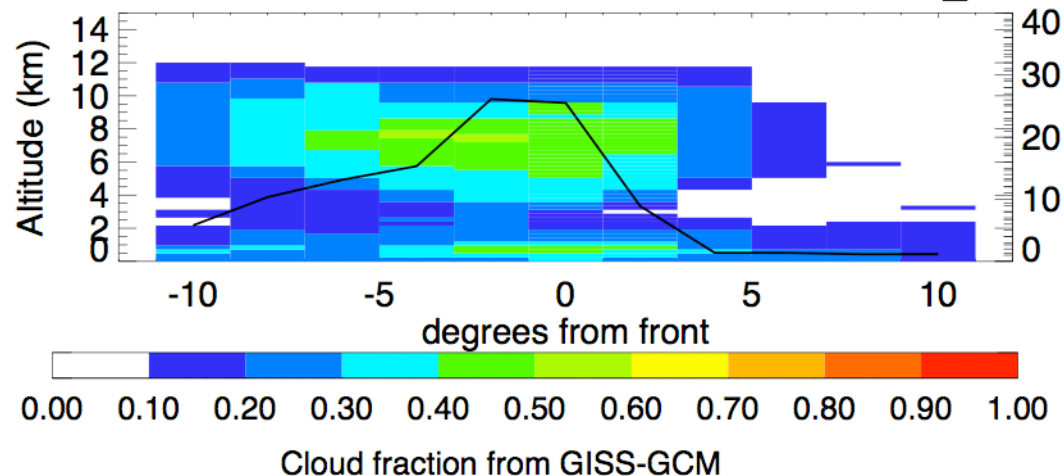
- Use GISS model-E 2°x2.5°x40L (6F32, August 2005) instead of NCEP, and combine simulated stratiform and convective cloud fraction instead of CloudSat, 1 winter (Nov-Mar), 33 warm fronts
- Low-level clouds ok, high-level clouds in warm sector ok, but problems in frontal zone: parameterization? Missing processes?

Differences explored: cloud parameterization

- Cloud formation based on RH

Composite of RH for same cross sections across warm fronts:

NCEP

GCM
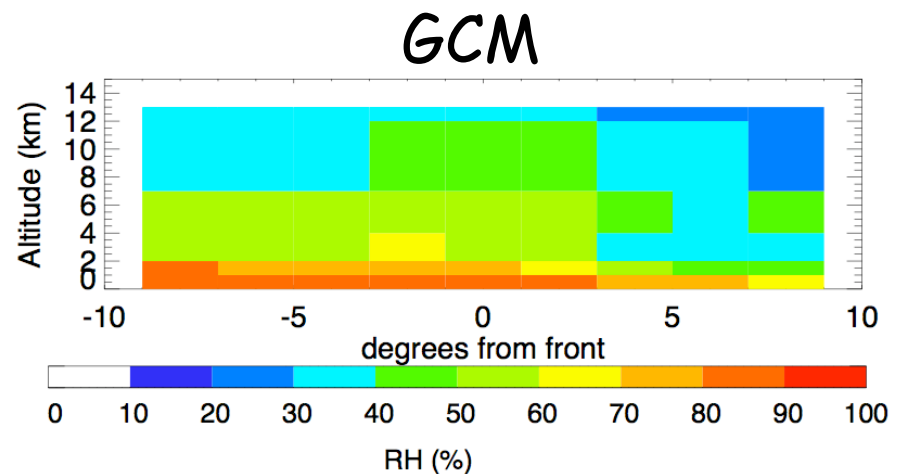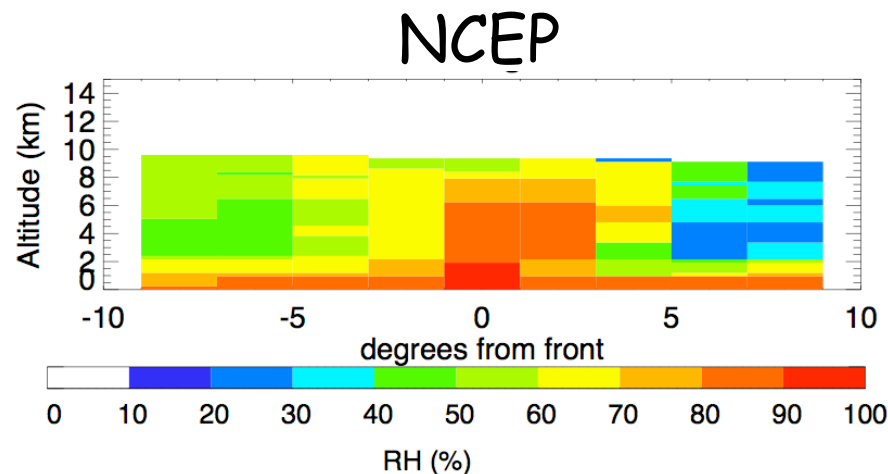
⇒ Humidity in GCM not lifted
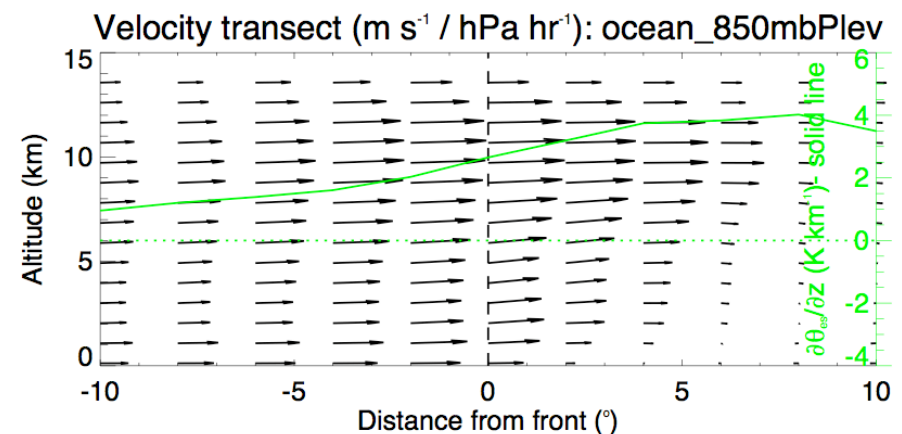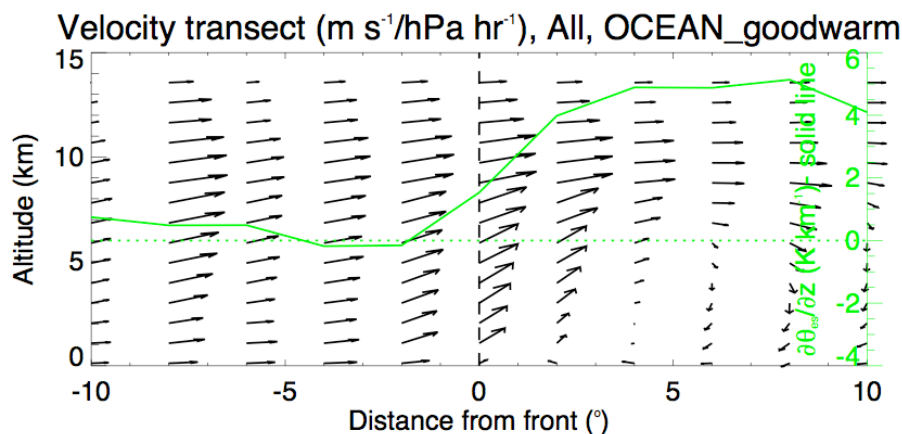=> Problem with dynamics?

Differences explored: dynamics?

- Composites of wind speed and vertical velocity across warm fronts:

  Composite of velocity for same cross sections across warm fronts:
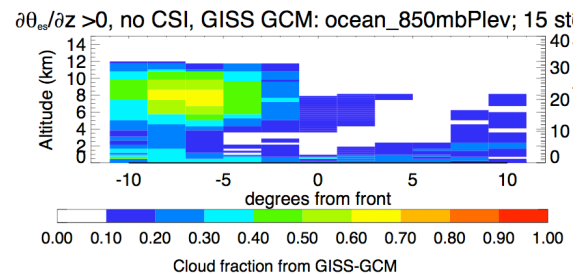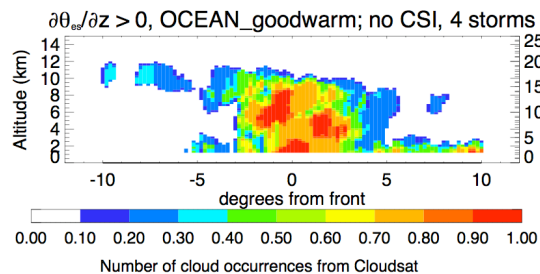
  NCEP   GCM

⇒ Vertical velocity too weak in GCM
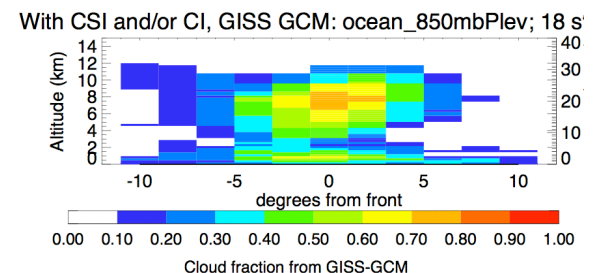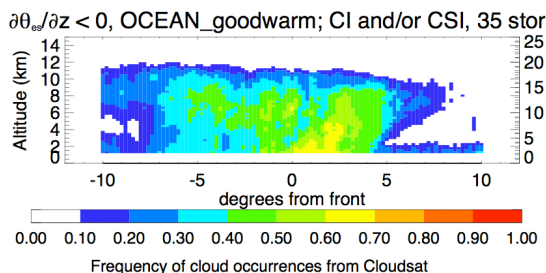
Differences explored: impact of convection?

- straight or slantwise convection. How often are conditional instability (CI) and conditional symmetric instability (CSI) happening somewhere in warm sector/front?

% of storms	NCEP (39 storms)	GCM (33 storms)
No CI, no CSI	10%	45%
CI and/or CSI	90%	55%

No CI, no CSI =>

CI and/or CSI =>

$\partial\theta_{es}/\partial z > 0$, OCEAN_goodwarm; no CSI, 4 storms

Number of cloud occurrences from Cloudsat

$\partial\theta_{es}/\partial z > 0$, no CSI, GISS GCM: ocean_850mbPlev; 15 st

Cloud fraction from GISS-GCM

$\partial\theta_{es}/\partial z < 0$, OCEAN_goodwarm; CI and/or CSI, 35 stor

Frequency of cloud occurrences from Cloudsat

With CSI and/or CI, GISS GCM: ocean_850mbPlev; 18 s

Cloud fraction from GISS-GCM

Preliminary conclusions

- Clouds in warm fronts occur less often in GCM, especially at mid-level, than in CloudSat observations

- Contamination of CloudSat cloud composites with precipitation

- problems with GCM:
  - vertical velocities too weak in GCM, humidity not lifted high enough across warm fronts
  - conditional and conditional symmetric instabilities occur less often in GCM than NCEP, but when they do, better agreement for frontal clouds